Amirkabir University of Technology
(Tehran Polytechnic)
Vol. 46, No. 1, Summer 2014, pp. 29- 31

Amirkabir Journal of Science & Research (Mechanical Engineering)
(AJSR - ME)

Experimental Study on Heat Transfer and Pressure Drop of TiO_2- Water Nanofluid

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(Received 13 Mar 2012, Accepted 11 Jun 2013)

ABSTRACT

In the current paper, heat transfer and pressure drop of TiO_2-water nanofluid are investigated at nanoparticles volume fraction between 0.002 and 0.2, and Reynolds number between 8000 and 49000 experimetally in a double tube counter-flow heat exchanger. The results show that the Nusselt number and pressure drop of the nanofluid increase by increasing the nanoparticles volume fraction or Reynolds number, and the pressure drop of the nanofluid is higher than the base fluid. The increament percentage in pressure drop of the nanofluid compared to the base fluid is higher at lower Reynolds number. The enhancement value in the Nusselt number decreased with increasing the Reynolds number at 0.002 nanoparticles volume fraction. The Nusselt number increment value for nanoparticles volume fractions of 0.01 and 0.02 are identical for all Reynolds number. Therefore, more efficiency obtained at low Reynolds number through using nanofuid with 0.002-volume fraction, and at high Reynolds number for 0.01 and 0.02 volume fractions.

KEYWORDS

Experimental Study, TiO2-Water Nanofluid, Nusselt Number, Heat Transfer, Pressure Drop, TuRbulence Flow.

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1- INTRODUCTION

Suspending small solid particles in the size of micrometer in the fluids is a method that was proposed many years ago to enhance the heat transfer rate. Some serious problems emerged by the use of these type of fluid. About a decade ago, particles in size of micrometer were replaced by nanometer-sized particles in the base fluid and nanofluid created. Many experimental studies reported that nanofluids have shown special advantages, such as better stability, greater thermal conductivity, and lower pressure drop rather than the base fluids. However, none of these benefits might occur together. He et. al [1] studied on the heat transfer of TiO_2-water nanofluid in a vertical pipe. The maximum Re number was 6000 and the maximum nanofluid concentration was 1.18% vol. The resullts show that the heat transfer of nanofluid enhances up to 40%. Duangthongsuk and Wongwises [2] studied the heat transfer coefficient and the friction factor of the TiO_2–water nanofluids in a horizontal double tube counter-flow heat exchanger at Reynolds number between 3000 and 18,000, and up to 2 %vol. The heat transfer coefficient of nanofluids with 1 %vol. was approximately 26% greater than the heat transfer coefficient of the base fluids, while for the volume concentration of 2.0 %vol. was approximately 14% lower than that of the base fluids. The pressure drop of the nanofluids was slightly higher than the base fluid and increased with increasing the nanofluid concentrations. By considering other researchs, it is observed that most of the experiments [1,2,3] on the heat transfer and pressure drop of nanofluid are done for Reynolds number lower than 18000. It is also seen that some of the experiments [1,2,4,5] are at the low volume concentration (about 1%) of the nanofluid. Therefore, in this paper, we investigated the heat transfer and pressure drop of the nanofluid for Reynolds number up to 49000 and the volume concentration of 0.2%vol. up to 2 %vol., experimentally.

2- EXPERIMENTAL APPARATUS

The experimental apparatus is built in three cycles as shown if Fig. 1. The nanofluid cycle contains the test section (double tube counter flow heat exchanger) to warm the nanofluid, and a water heat exchanger in order to cool the nanofluid. Two K-type thermocouples were measured the bulk temperature of the flow at the inlet and the outlet of the test section. Eight K-type thermocouples were installed so that the temperature of the inner surface of the tube was measured without affecting the nanofluid flows. The second cycle contains the equipments to create and control the flow rate of hot water at the desired temperature. The nanofluid was heated at the test section by hot water. The third cycle contains condensing unit in order to cool the nanofluid. A 48.5 degrees slop mercury manometer was used to measure the pressure drop.

The specified amount of Titania nanoparticles with the diameter of 10 nm solved at the distilled water in order to create nanofluid at different concentration. Ultrasonic vibration, magnetic stirrer and cetyl trimethyl ammonium bromide were used to create adequate nanofluid.

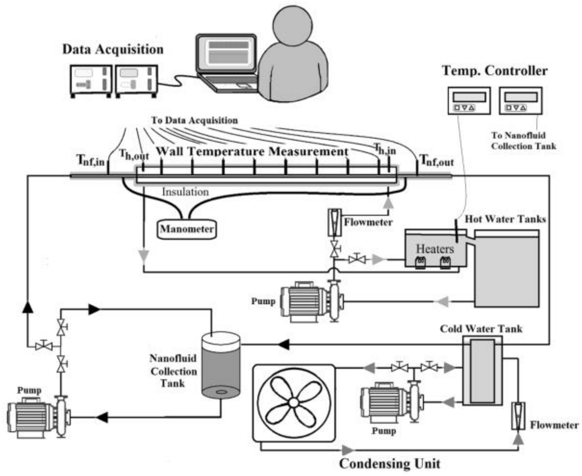

Fig. 1. Schematic diagram of the experimental apparatus.

3- METHODOLOGY

Corcione correlation [6] are used for the determination of the nanofluid effective thermal conductivity and dynamic viscosity. The heat transfer coefficient and mean Nusselt number of the nanofluid are defined as follows:

$$\bar{h}_{nf} = \frac{\dot{Q}_{avg}}{A(T_{wall} - T_{in,nf})} \tag{1}$$

$$\bar{N}u_{nf} = \frac{\bar{h}_{nf} D}{k_{nf}} \tag{2}$$

The parameters A, Q, T, and D refer respectively to the heat transfer area, heat transfer rate, temperature, and inner diameter of the tube. The pressure drop of the nanofluid is calculated from the following equation that ‘h’ is the difference between height of mercury manometer columns. The parameters ‘ρ’ and ‘g’ are density and earth acceleration at laboratory location, respectively:

$$\Delta p = (\rho_{Hg} - \rho_0) gh \ \sin(48.5^o) \tag{3}$$

4- RESUlTS AND DISCUSSIOM

Fig. 2 presents the mean Nusselt number for the nanofluid and distilled water. The values of uncertainties are calculated in both low and high Reynolds numbers. The maximum uncertainties of Nusselt number at lowest and highest Reynolds number are about 3% and 4.7% for nanoparticle volume fraction 0.01. The maximum uncertainty of Reynolds number is 0.6%. The maximum uncertainties of pressure drop at the nanoparticle volume fraction of 0.01 are about 0.20% and 3.6% for the highest and lowest Reynolds number respectively.

The results indicate that the nanofluid has a higher Nusselt number compared to the base fluid. The Nusselt number increases by increasing the nanofluid concentration. Meanwhile, the Nusselt number for all nanofluids and distilled water increases by increasing the Reynolds number. The Nusselt number at the higher Reynolds numbers, presents more enhancements by increasing nanofluid concentration compared to the low

Reynolds numbers. The importance of this result unfolds by considering the results of pressure drop.

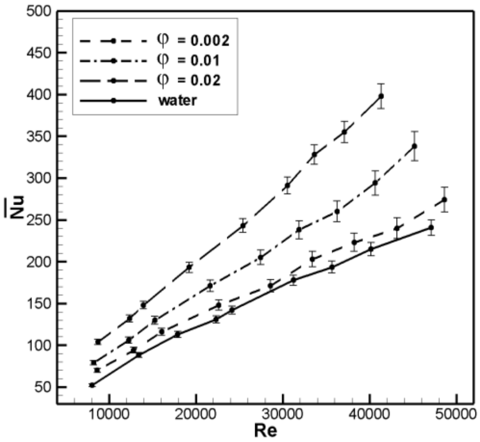

Fig. 2. Nusselt number against the Reynolds number for the nanofluid and distilled water

Fig. 3 depicts the values of the pressure drop of the nanofluid for different nanoparticles volume fraction. Similar trend to the Nusselt number is observed for the pressure drop. The pressure drop increases by increasing the nanoparticles volume fraction. Meanwhile, the pressure drop for all nanofluids and distilled water increases by increasing the Reynolds number. The pressure drop of the nanofluid with nanoparticles volume fraction of 0.002 is near to the pressure drop of the base fluid, by considering uncertainty values especially at low Reynolds number. As mentioned before, the nanofluid with concentration of 0.002 has higher heat transfer rate and equal pressure drop compared to distilled water especially at low Reynolds number. Nanofluids with concentrations of 0.01 and 0.02, show significant increment in the heat transfer and pressure drop at all Reynolds number. Considering current cost, someone can suggest the use of nanofluid with low volume concentration (lean nanofluid) for low Reynolds number flows.

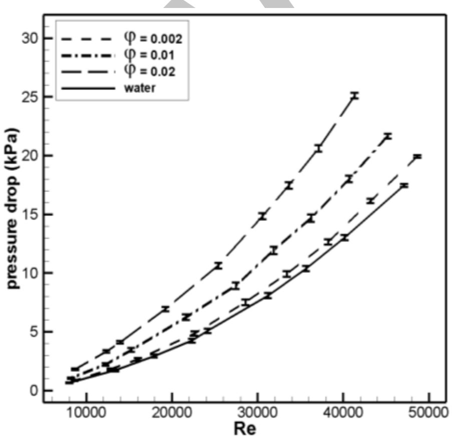

Fig. 3. Pressure drop against the Reynolds number for the nanofluid and distilled water

5- ConclUsion

An experimental study performed in order to investigate the effect of nanoparticles volume fraction of TiO_2–water nanofluid on the heat transfer characteristic and pressure drop in a wide range of nanoparticles volume fraction and Reynolds number in turbulent flow. It is observed that by increasing the Reynolds number or nanoparticle volume fraction, the Nusselt number and pressure drop increases. Meanwhile all nanofluids have a higher Nusselt number and pressure drop compared to the distilled water. The heat transfer rate of the nanofluid with concentration of 0.002 is higher than base fluid, while both of them show the same pressure drop at low Reynolds number. Nanofluid with concentrations of 0.01 and 0.02, show significant increment in the both of heat transfer and pressure drop. Therefore, using the lean nanofluid at low Reynolds number is recommended.

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